

COCCINELLIDAE (COLEOPTERA) IN APPLE ORCHARDS OF EASTERN WEST VIRGINIA AND THE IMPACT OF INVASION BY *HARMONIA AXYRIDIS*¹

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ABSTRACT: Twenty-five species of Coccinellidae were found on apple in eastern West Virginia from 1983 to 1996. From 1989 through 1994, the exotic coccinellid, *Coccinella septempunctata* (first collected in 1983), has dominated the fauna of the tribe Coccinellini. Another adventive species, *Harmonia axyridis* (first collected in 1994), became the dominant species in the tribe Coccinellini in 1995, and continues to dominate the coccinelline guild on apple. *Harmonia axyridis* has displaced *C. septempunctata* and is providing better biological control of *Aphis spiraeicola* on apple in eastern West Virginia.

Coccinellids (Coleoptera: Coccinellidae) are an important group of aphid predators in many ecosystems. Because of their ability to contribute to the control of pests, many coccinellids have been selected for introduction in biological control programs. As of 1985, there had been 179 introductions of coccinellids into the U. S., with 26 species having become established; however, 8 were a result of accidental introductions (Gordon 1985). Two recent coccinellid immigrants have made an obvious impact in the mid-Atlantic states. In 1973, *Coccinella septempunctata* L. was first found in New Jersey (Angalet et al. 1979), and it gradually spread throughout the Northeast (Schaefer et al. 1987). In 1988, *H. axyridis* was first found in Louisiana (Chapin and Brou 1991), and has since spread into the mid-Atlantic region (Day et al. 1994). Although both species had been released intentionally, their establishment appears to be a result of accidental introductions (Day et al. 1994). Both species are now abundant throughout much of the northeastern United States and eastern Canada (Hoebeke and Wheeler 1996) and have even become subjects of public concern because of occasional massive migrations of *C. septempunctata* (Schaefer et al. 1987) and by large numbers of *H. axyridis* overwintering in houses (Knodel and Hoebeke 1996).

There have been numerous studies cataloguing the coccinellids in apple orchards in Europe and North America. In Europe, more than 23 species of coccinellids have been collected on apple, but usually 3 to 14 species in any one study (Hodek and Honěk 1996). In a study spanning 4 years in 3 regions of Hungary, 23 coccinellid species were found on apple (Markó et al. 1995). In Europe, *Adalia bipunctata* (L.) and *C. septempunctata* dominate in apple

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orchards. The number of coccinellid species recorded from North American orchards has been similar to that reported in Europe: 7 species in Ontario (Smith 1957), 17 in another study in Ontario (Hagley 1974), 15 in Quebec (LeRoux 1960), 8 in Washington state (Carroll and Hoyt 1984), and 6 in Pennsylvania (Horsburgh and Asquith 1968). Putman (1964) found 10 species of coccinellids in peach orchards in Ontario. In Washington, *Coccinella transversoguttata* Faldermann was the most abundant (Carroll and Hoyt 1984) but in the east, the dominant species varied temporally and spatially. In this paper, we characterize the coccinellid fauna of apple orchards in eastern West Virginia. Data are taken from several studies covering a 14-year period, 1983 to 1996. These years span the time of the invasion of *H. axyridis* into the region and are used to evaluate the effect of *H. axyridis* on other species in the tribe Coccinellini, and on *Aphis spiraecola* Patch (Homoptera: Aphididae) populations.

MATERIALS AND METHODS

Data from several studies were used to characterize the Coccinellidae in apple orchards in eastern West Virginia. Except for the years 1993 to 1995, both conventionally managed and unsprayed orchards were sampled in each study. Data from 1983 to 1984 were taken from Brown and Adler (1989), and Brown et al. (1988). These studies covered the region from Virginia to New York, but only data from West Virginia are used in the present paper. Sampling consisted of visual examination of 7 branches from 6 trees in each of 4 orchards, repeated 6 times per year. The purpose of the study was to examine the phytophagous community structure on apple, but occurrence, not abundance, of natural enemies was also recorded. Data from 1984 to 1988 were from Brown and Welker (1992) using whole-tree visual sampling from 5 to 10 trees from each of 3 orchards, 4 to 6 times per year. Data from 1989 to 1990 were from Brown (1993), sampling in 2 orchards, 2 branches from each of 10 trees in 1989 and 5 trees in 1990, 6 samples per year. Data from 1991 were taken from limb-jarring samples from 3 branches of 6 apple trees each hour over a 24-hour period 4 times during the summer. Limb-jarring samples from 2 peach trees per hour and one sour cherry tree every other hour provide data for Coccinellidae on those tree species. A second study in 1991 added data for Coccinellidae on peach trees (Brown and Puterka 1997) and used observations on 6 branches from each of 6 trees in 3 orchards at 5 times during the summer.

Coccinellid data from 1992 to 1996 were based largely on two experimental orchards planted in 1992: one managed with conventional methods, and the second managed with reduced insecticides and diverse ground cover plantings underneath the trees. In 1992, sampling involved two, 15-tree transects per orchard 6 times per year (Brown and Lightner 1997). Every terminal on each sample tree was examined for aphids and predators. Monthly samples from 10 randomly selected trees per orchard, 10 shoots per tree, were collected from

1993 to 1995 (Brown et al. 1997). In 1996 the same two orchards were sampled more intensively to estimate populations of *A. spiraecola* and aphid predators. Ten terminals on 20 randomly selected trees were sampled weekly in May and June, then biweekly into September whenever aphids were present. In 1992 and 1996, three other orchards were also sampled with the same methodology as described above for those years.

Identification of adult Scymninae, Sticholotidinae, and Psylloborini were made by R. D. Gordon, USDA, ARS, Systematic Entomology Laboratory, Washington, DC. Adult Coccinellinae (except Psylloborini) and Chilocorinae were identified using Dillon and Dillon (1961).

Data on populations of *A. spiraecola*, the predominant aphid on apple trees in West Virginia (Pfeiffer et al. 1989), resulted from pest monitoring in three conventionally managed apple orchards. Ten terminals on two trees from each orchard were sampled and the number of leaves per terminal infested with aphids was recorded. Sampling was conducted every week from early May to September from 1992 to 1996.

Assessment of the impact of *H. axyridis* on coccinellids was limited to the tribe Coccinellini. Any effect on the endemic fauna would be expected to be greatest on members of the same tribe because of their generally similar biologies and niche requirements.

RESULTS AND DISCUSSION

Twenty-five species of coccinellids in 4 subfamilies and 9 tribes were found on apple in eastern West Virginia from 1983 to 1996 (Table 1). Fourteen species of coccinellids were found on peach, including *Scymnus caudalis* LeConte, which was not found on apple, and 7 on sour cherry in limited sampling on these host trees (Table 1). In addition to those species listed, 4 others, all belonging to the Coccinellini, were caught in sticky or blacklight traps located in apple orchards but were not seen foraging on fruit trees: *C. transversoguttata*, *Hippodamia convergens* Guerin, *H. tredecimpunctata tibialis* (Say), and *Mulsantina picta* (Randall). The 25 species listed in Table 1 represent a larger and more comprehensive list of the coccinellid fauna on apple than other studies because it covers a 14-year period, whereas all previous studies, except for Markó et al. (1995), covered only 1 to 3 years.

For the 8 years in which numerical data are available (1989 to 1996), the two exotic species, *C. septempunctata* and *H. axyridis*, dominated the coccinelline fauna (Table 2). Although 7 species of Coccinellini were recorded on apple during these years, over 70% of the individuals collected belonged to the two exotic species. *Coccinella septempunctata* was first collected from apple in West Virginia in 1983. By 1985, *C. septempunctata* was the most frequently encountered coccinelline in orchards, and it was the only coccinelline

Table 1. Coccinellidae, by subfamily and tribe (after Kovář 1996), found in apple orchards of eastern West Virginia, 1983-1996.

Scymninae	Coccinellinae
Stethorini	Coccinellini
<i>Stethorus punctum</i> (LeConte) 1	<i>Adalia bipunctata</i> (L.) ¹
Scymnillini (Zilini)	<i>Anatis labiculata</i> (Say)
<i>Zilus horni</i> Gordon	<i>Anatis mali</i> (Say) 1
Scymnini	<i>Coccinella novemnotata</i> Herbst
<i>Diomus terminatus</i> (Say) 1,2	<i>C. septempunctata</i> L. 1,2
<i>Scymnus fraternus</i> LeConte	<i>C. transversoguttata</i> Faldermann
<i>S. circumspectus</i> Horn 2	<i>Coleomegilla maculata lengi</i>
<i>S. iowensis</i> Casey 1,2	Timberlake 1
<i>S. rubricaudus</i> Casey	<i>Cycloneda munda</i> (Say) 1
<i>Scymnus</i> sp. 1	<i>C. sanguinea</i> (L.)
Brachiacanthini	<i>Harmonia axyridis</i> (Pallas)
<i>Brachiacantha ursina</i> (F.)	<i>Hippodamia parenthesis</i> (Say)
Hyperaspidini	<i>Olla v-nigrum</i> (Mulsant) 1
<i>Hyperaspis proba</i> (Say) 1,2	Psylloborini
Chilocorinae	<i>Psyllobora vigintimaculata</i> (Say) 2
Chilocorini	Sticholotidinae
<i>Chilocorus stigma</i> (Say) 1,2	Microweiseini
	<i>Microweisea misella</i> (LeConte) 1

¹ Also found on peach trees; *Scymnus caudalis* LeConte (Scymninae: Scymnini) was found only on peach trees.

² Also found on sour cherry trees.

Table 2. Percentage composition of the coccinelline fauna on apple in eastern West Virginia, 1989-1996.

Species	1989-90	1991	1992	1993	1994	1995	1996
<i>C. septempunctata</i>	72.7	86.4	99.5	93.2	79.4	9.1	10.2
<i>A. bipunctata</i>	9.1	2.3		1.7			
<i>C. munda</i>	9.1	4.5	0.5				
<i>A. labiculata</i>	9.1						
<i>C. maculata lengi</i>		2.3		5.1	2.9	27.3	1.1
<i>O. v-nigrum</i>		4.5					
<i>H. axyridis</i>					17.7	63.6	88.7
Number observed	11	44	192	59	34	11	265

seen in 1987 and 1988 during sampling of the same orchards (Kozár et al. 1994). *Coccinella novemnotata* Herbst, which Wheeler and Hoebeke (1995) suggest may be negatively correlated with *C. septempunctata*, has not been seen in West Virginia apple orchards since 1985. In a survey prior to the arrival of *C. septempunctata* in nearby south-central Pennsylvania (Horsburgh and Asquith 1968), the only Coccinellini found were *A. bipunctata*, *C. munda*, and *H. convergens*.

Harmonia axyridis, first collected in 1994, has replaced *C. septempunctata* as the dominant coccinelline in apple orchards (Fig. 1). In 1995, *C. septempunctata* was reduced to the third most abundant species of Coccinellini behind *H. axyridis* and *Coleomegilla maculata lengi* Timberlake (Table 2). Of

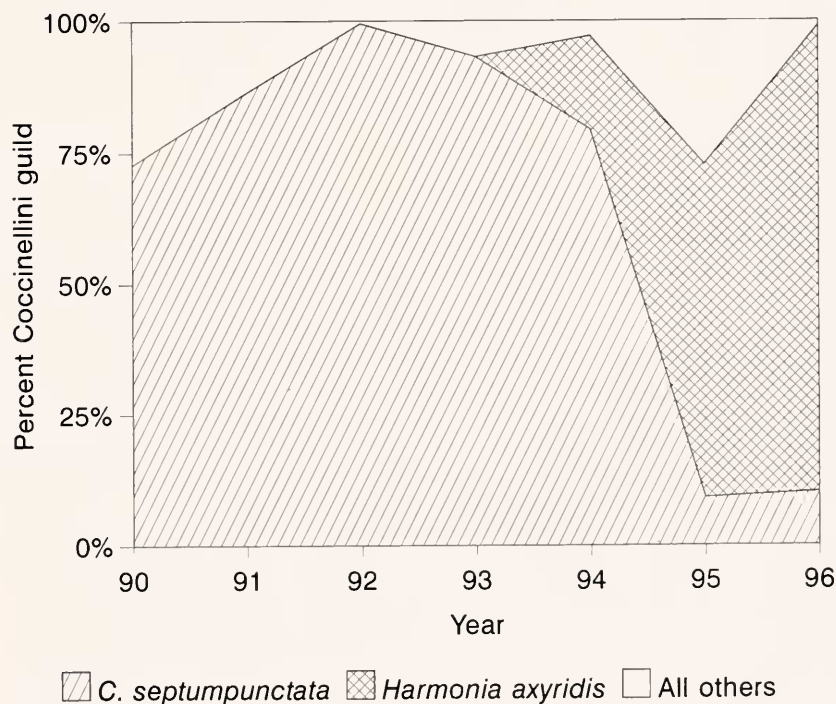


Fig. 1. Percentage composition of the coccinelline fauna in apple orchards of eastern West Virginia from 1990 to 1996, showing the displacement of *C. septempunctata* by *H. axyridis*.

the less abundant coccinellids, *A. bipunctata*, *Cycloneda munda* (Say), *Anatis labiculata* (Say), and *Olla v-nigrum* (Mulsant) have not been seen in apple orchards in the three years since *H. axyridis* appeared. Only *C. maculata lengi* has seemed to become more abundant on apple since the arrival of *H. axyridis*. *Harmonia axyridis* has shown its ability to rapidly dominate in other ecosystems in other regions where it has invaded (Teddners and Schaefer 1994, Day et al. 1994).

Comparing the two years in which intensive sampling of aphid predators was conducted, 1992 and 1996, gives insight into the interaction between *C. septempunctata* and *H. axyridis* (Table 3). In 1992, all but one coccinelline

Table 3. Number of Coccinellini collected in two intensive surveys of aphid predators in eastern West Virginia apple orchards.

Species	1992		1996	
	Adults	Immatures	Adults	Immatures
<i>C. septempunctata</i>	92	99	27	0
<i>C. munda</i>	1	0	0	0
<i>H. axyridis</i>	0	0	48	187
<i>C. maculata lengi</i>	0	0	3	0
Unidentified	0	0	0	12

was *C. septempunctata*, with about equal numbers of adults and immatures. By 1996, two years after *H. axyridis* was first detected, no *C. septempunctata* immatures were seen on apple trees. The 12 unidentified immatures were either egg masses or first instar larvae that we could not identify to species. The reduction in total numbers of *C. septempunctata* from 1992 to 1996 suggests that *H. axyridis* not only replaced *C. septempunctata* as the dominant species but also largely displaced it from apple, especially in its use of apple as a larval habitat. It has been shown in Japan that *H. axyridis* larvae prey on *C. septempunctata brucki* Mulsant, but predation in the reverse direction does not occur (Hironori and Katsuhiko 1997).

The displacement of *C. septempunctata* by *H. axyridis* has had a positive impact on biological control of *A. spiraecola* in West Virginia apple orchards (Fig. 2.). Aphid populations were much lower from 1994 to 1996 than in previous years; peak aphid populations were lower and the duration of aphid infestations was shorter, particularly in 1996 (Fig. 2). The aphid data were from orchards sprayed with insecticides, explaining the sharp declines in population abundance in most years. *Harmonia axyridis* was first found in apple orchards in 1994, but it did not dominate until 1995, when aphid populations appeared to be suppressed. Only in 1995 and 1996, the two years in which *H.*

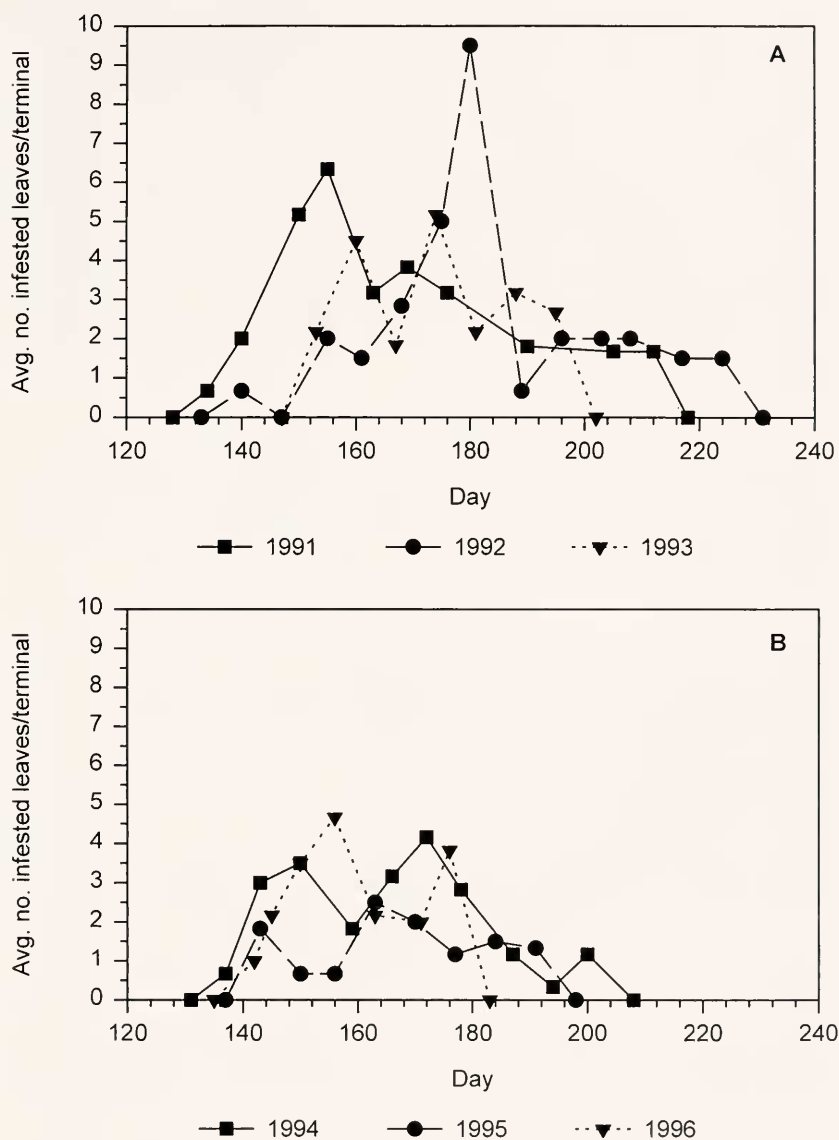


Fig. 2. Population estimates of *A. spiraeicola* by day of the year in three conventionally managed orchards in eastern West Virginia; A, 1991 to 1993, prior to arrival of *H. axyridis*; B, 1994-1996, after arrival of *H. axyridis*.

axyridis dominated the coccinelline fauna, were insecticide sprays not applied to control aphids. Data on aphids were obtained only from a few trees in three orchards in only one location and, therefore, cannot be considered conclusive. The indication, however, is that the arrival of *H. axyridis* has improved the biological control of aphids on apple.

Conclusions: Exotic species of Coccinellini have greatly affected the coccinelline fauna of West Virginia apple orchards. First, *C. septempunctata* dominated the fauna, but it was in turn displaced by the newly arrived *H. axyridis* in 1995. The overall effect of *H. axyridis* on native Coccinellini has not been evaluated, but since the arrival of *C. septempunctata*, native coccinellines have represented only a very minor component of the fauna on apple. Aphid biological control has been enhanced since the arrival of *H. axyridis*, so this latest addition to the coccinelline fauna has been beneficial in the apple agroecosystem.

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LITERATURE CITED

- Angalet, G. W., J. M. Tropp, and A. N. Eggert. 1979. *Coccinella septempunctata* in the United States: recolonizations and notes on its ecology. *Environ. Entomol.* 8: 896-901.
- Brown, M. W. 1993. Resilience of the natural arthropod community on apple to external disturbance. *Ecol. Entomol.* 18: 169-183.
- Brown, M. W. and C. R. L. Adler. 1989. Community structure of phytophagous arthropods on apple. *Environ. Entomol.* 18: 600-607.
- Brown, M. W., C. R. L. Adler, and R. W. Weires. 1988. Insects associated with apple in the mid-Atlantic states. *New York's Food and Life Sci. Bull.* No. 124, 1-31.
- Brown, M. W., D. M. Glenn, and T. van der Zwet. 1997. Impact of ground cover plants on pest management in West Virginia, USA, apple orchards. *Hortic. Sci. (Prague)* 24:39-44.
- Brown, M. W. and G. W. Lightner. 1997. Recommendations on minimum experimental plot size and succession of aphidophaga in West Virginia, USA, apple orchards. *Entomophaga* 42: 259-269.
- Brown, M. W. and G. J. Puterka. 1997. Orchard management effects on the arthropod community on peach with comparisons to apple. *J. Entomol. Sci.* 32: 165-182.
- Brown, M. W. and W. V. Welker. 1992. Development of the phytophagous arthropod community on apple as affected by orchard management. *Environ. Entomol.* 21: 485-492.
- Carroll, D. P. and S. C. Hoyt. 1984. Natural enemies and their effects on apple aphid, *Aphis pomi* DeGeer (Homoptera: Aphididae), colonies on young apple trees in central Washington. *Environ. Entomol.* 13: 469-481.
- Chapin, J. B. and V. A. Brou. 1991. *Harmonia axyridis* (Pallas), the third species of the genus to be found in the U.S. (Coleoptera: Coccinellidae). *Proc. Entomol. Soc. Wash.* 93: 630-635.

- Day, W. H., D. R. Prokrym, D. R. Ellis, and R. J. Chianese. 1994. The known distribution of the predator *Propylea quatuordecimpunctata* (Coleoptera: Coccinellidae) in the United States, and thoughts on the origin of this species and five other exotic lady beetles in eastern North America. *Entomol. News* 105: 244-256.
- Dillon, E. S. and L. S. Dillon. 1961. A manual of common beetles of eastern North America. Row, Peterson & Company. Evanston, Ill.
- Gordon, R. D. 1985. The Coccinellidae (Coleoptera) of America north of Mexico. *J. New York Entomol. Soc.* 93: 1-912.
- Hagley, E. A. C. 1974. The arthropod fauna in unsprayed apple orchards in Ontario. II. Some predacious species. *Proc. Entomol. Soc. Ont.* 105: 28-40.
- Hironori, Y. and S. Katsuhiko. 1997. Cannibalism and interspecific predation in two ladybirds in relation to prey abundance in the field. *Entomophaga*. 42: 153-163.
- Hoebeke, E. R. and A. G. Wheeler. 1996. Adventive lady beetles (Coleoptera: Coccinellidae) in the Canadian maritime provinces, with new eastern U.S. records. *Entomol. News* 107: 281-290.
- Hodek, I. and A. Honěk. 1996. Ecology of Coccinellidae. Kluwer Academic Publishers. Boston.
- Horsburgh, R. L. and D. Asquith. 1968. Initial survey of arthropod predators of the European red mite in south-central Pennsylvania. *J. Econ. Entomol.* 61: 1753-1754.
- Knodel, J. J. and E. R. Hoebeke. 1996. Multicolored Asian lady beetle, *Harmonia axyridis* (Pallas) Coleoptera: Coccinellidae. Cornell Coop. Ext., Misc. Pest Management Fact Sheet, page 101.00.
- Kováč, I. 1996. Phylogeny. In: Hodek, I. and A. Honěk. Ecology of Coccinellidae. Kluwer Academic Publishers. Boston. pp: 19-31.
- Kozár, F., M. W. Brown and G. Lightner. 1994. Spatial distribution of homopteran pests and beneficial insects in an orchard and its connection with ecological plant protection. *J. Appl. Entomol.* 117: 519-529.
- LeRoux, E. J. 1960. Effects of "modified" and "commercial" spray programs on the fauna of apple orchards in Quebec. *Ann. Soc. Entomol. Quebec* 6: 87-121.
- Markó, V., O. Merkl, A. Podlussány, K. Vig, Cs. Kutasi, and S. Bogya. 1995. Species composition of Coleoptera assemblages in the canopies of Hungarian apple and pear orchards. *Acta Phytopathol. Entomol. Hung.* 30: 221-245.
- Pfeiffer, D. G., M. W. Brown, and M. W. Varn. 1989. Incidence of spirea aphid (Homoptera: Aphididae) in apple orchards of Virginia, West Virginia, and Maryland. *J. Entomol. Sci.* 24: 145-149.
- Putman, W. L. 1964. Occurrence and food of some coccinellids (Coleoptera) in Ontario peach orchards. *Can. Entomol.* 89: 1149-1155.
- Schaefer, P. W., R. J. Dysart, and H. B. Specht. 1987. North American distribution of *Coccinella septempunctata* (Coleoptera: Coccinellidae) and its mass appearance in coastal Delaware. *Environ. Entomol.* 16: 368-373.
- Smith, B. C. 1957. Notes on relative abundance and variation in elytral patterns of some common coccinellids in the Belleville district (Col.: Coccinellidae). *Rep. Entomol. Soc. Ont.* 88: 59-60.
- Tedders, W. L. and P. W. Schaefer. 1994. Release and establishment of *Harmonia axyridis* (Coleoptera: Coccinellidae) in the southeastern United States. *Entomol. News* 105: 228-243.
- Wheeler, A. G., Jr. and E. R. Hoebeke. 1995. *Coccinella novemnotata* in northeastern North America: Historical occurrence and current status (Coleoptera: Coccinellidae). *Proc. Entomol. Soc. Wash.* 97: 701-716.